AN INTERSTELLAR ISOTOPIC SIGNATURE RECORDED IN ALTERED PYROXENE CHONDRULES

E. DELOULE: CRPG-CNRS, 15 rue Notre-Dame des Pauvres, BP20 54501 Vandoeuvre France
J-P. DOUKHAN : Lab. Etat Solide. Univ. Lille-Flandres-Artois, 59655, Villeneuve d'Ascq France
F. ROBERT: Lab. de Minéralogie. Muséum-CNRS, 61 rue Buffon, 75005 Paris, France.

Abstract

A high abundance of hydroxide in the pyroxenes of meteoritic chondrules from the LL3 chondrites Bishunpur and Semarkona has been identified due to submicroscopic amphibole lamellae. Ion-microprobe analyses of these water-rich areas have shown that they have retained interstellar hydrogen isotopic ratios with D/H up to 479 $x10^{-6}$. Mesostases and olivines in these chondrules have been subjected to an intense alteration with a separate source of water having a D/H ratio (down to 63 $x10^{-6}$) close to the protosolar value (D/H = 31± 4 $x10^{-6}$ in protosolar H_2 *[1]*).

Experimental and sampling

The technical instrumental parameters for monitoring the ion-probe have been reported elsewhere *[2]*. The H^+/Si^+ signal is arbitrarily translated as ppm water with the assumption that H^+ is emitted from hydroxyls. The relative precision for water concentration lies between ±25% and ±10% for concentrations ranging between 500 and 10,000 ppm, respectively. Uncertainties on the D/H ratios arise from the absolute intensity of the H^+ signal and upon the accuracy of the calibration of the instrumental mass discrimination. 66% of the resulting calculated error bars lies between ±3 and ±12 $x10^{-6}$ with an average value at ±5 $x10^{-6}$ and a maximum of ±40 $x10^{-6}$ for the highest D/H ratios (2 standard deviations).

The chemical composition of the area analyzed with the ion-probe along with the redox state of the chondrules (i.e. Type I or II; *[3]*) were determined by electron microprobe analyses. Selected analyses of 130 areas belonging to 9 Type I and 5 Type II chondrules from Bishunpur and 2 Type I from Semarkona are reported in Fig. 1. In most cases, sputtered area represent a mixing of different mineralogical phases. This is illustrated by the large variations in the K/Si and Mg/Si ratios. In order to illustrate such a mixing, Fig. 1 is arbitrarily divided in 3 zones 1) low Mg/Si & high K/Si ratios correspond to mesostasis-rich area 2) high Mg/Si (up to 2.0) & low K/Si ratios correspond to olivine-rich area and 3) intermediate Mg/Si = 0.8±0.2 corresponds to pyroxene-rich area.

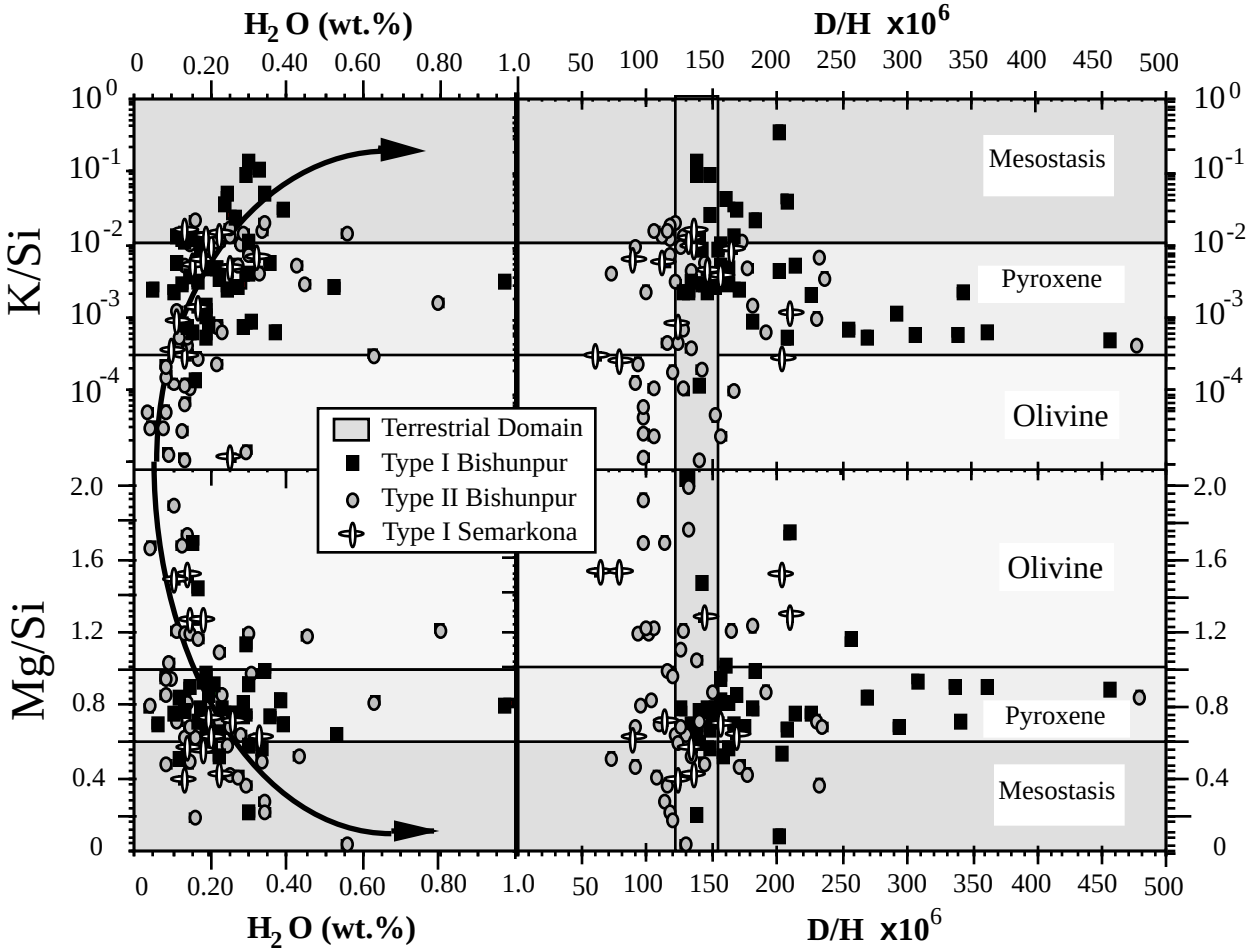
Mineralogical identification of water in pyroxene chondrules

In transmission electron microscopy the pyroxene grains show diffraction patterns consistent with low clino-enstatite (CE). High resolution images of some of these grains show irregular stacking of slabs parallel to $(010)_{CE}$. This cannot result from a large density of stacking faults on $(010)_{CE}$ because such faults are known to occur on $(100)_{CE}$. They must result from polytypism i.e. mixture of low CE and amphibole *[4]*. The amount of amphibole varies from place to place and can reach up to 50 vol.%. A series of analyses performed with a CAMEBAX microprobe (wave length dispersive spectrometry) within a "defective" CE grain and, for comparison, within a "normal" neighbouring CE grain, confirms the presence of anthophyllite ($Mg_7Si_8O_{22}(OH)_2$, space group Pnma).

Isotopic identification of water in chondrules

The mesostasis is systematically enriched in water compared to most pyroxenes and olivines, likely resulting from a parent body hydrothermal alteration (see arrows in Fig. 1). Olivine and mesostasis show low D/H ratios (down to 63 $x10^{-6}$) compared to pyroxene, indicating that olivine was probably also altered during this hydrothermal episode. The deuterium enrichment observed in Type I pyroxenes is much to large to result from isotopic fractionation occurring during this aqueous alteration or during chondrule melting. Therefore Type I pyroxene chondrules were altered by a second source of water either i) because deuterium-rich grains, presumably of interstellar origin (water ice or clays), were present among chondrule precursors or ii) because the chondrules were in

contact with water vapour at high temperature. Since the closure temperature for isotopic exchange between amphibole and water is 350-400°C, pyroxene in chondrules never reached isotopic equilibrium with the hydrothermal fluids which have circulated in their parent body .



Implications for the solar system D/H ratio.

The statistical mean of the D/H ratio in these LL3 chondrules (140±10 x10^{-6}) correspond to those in CC's or to the actual terrestrial value. These data demonstrate that - at least - two sources of water were intimately mixed in the solar system. Accordingly, solar system D/H variations may result from a different mixing ratio between a protosolar *[5]* (63 x10^{-6}; present mean value measured in olivines and in mesostases) and an interstellar water (730±120 x10^{-6}; measured in the Semarkona Smectites) *[6]*.

References

[1] D. GAUTIER ET PH. MOREL A&A (in presse) [2] E. DELOULE *et al.* 1991 Geochim. Cosmochim. Acta **V3** 53-62 (1991); Earth Planet Sci. Lett.**105**,543-553 (1991) Chem. Geol. 101, 187-192 (1992). [3] R. JONES Geochim. Cosmochim. Acta **58**, 5325-5340 (1994); D. Sears *et al.* [4] J-C DOUKHAN *et al.*Meteoritics **26**, 105-109 (1991) [5] E. DELOULE ET F. ROBERT Geochim. Cosmochim. Acta **59**, 4695-4706 (1995) [6] C. LÉCLUSE et F. ROBERT Geochim. Cosmochim. Acta **58**, 2927-2939 (1994)